



The ArgoNeuT and MicroBooNE Experiments at Fermi National Accelerator Laboratory

Mitch Soderberg,
on behalf of the ArgoNeuT and MicroBooNE Collaborations
ICHEP 2012

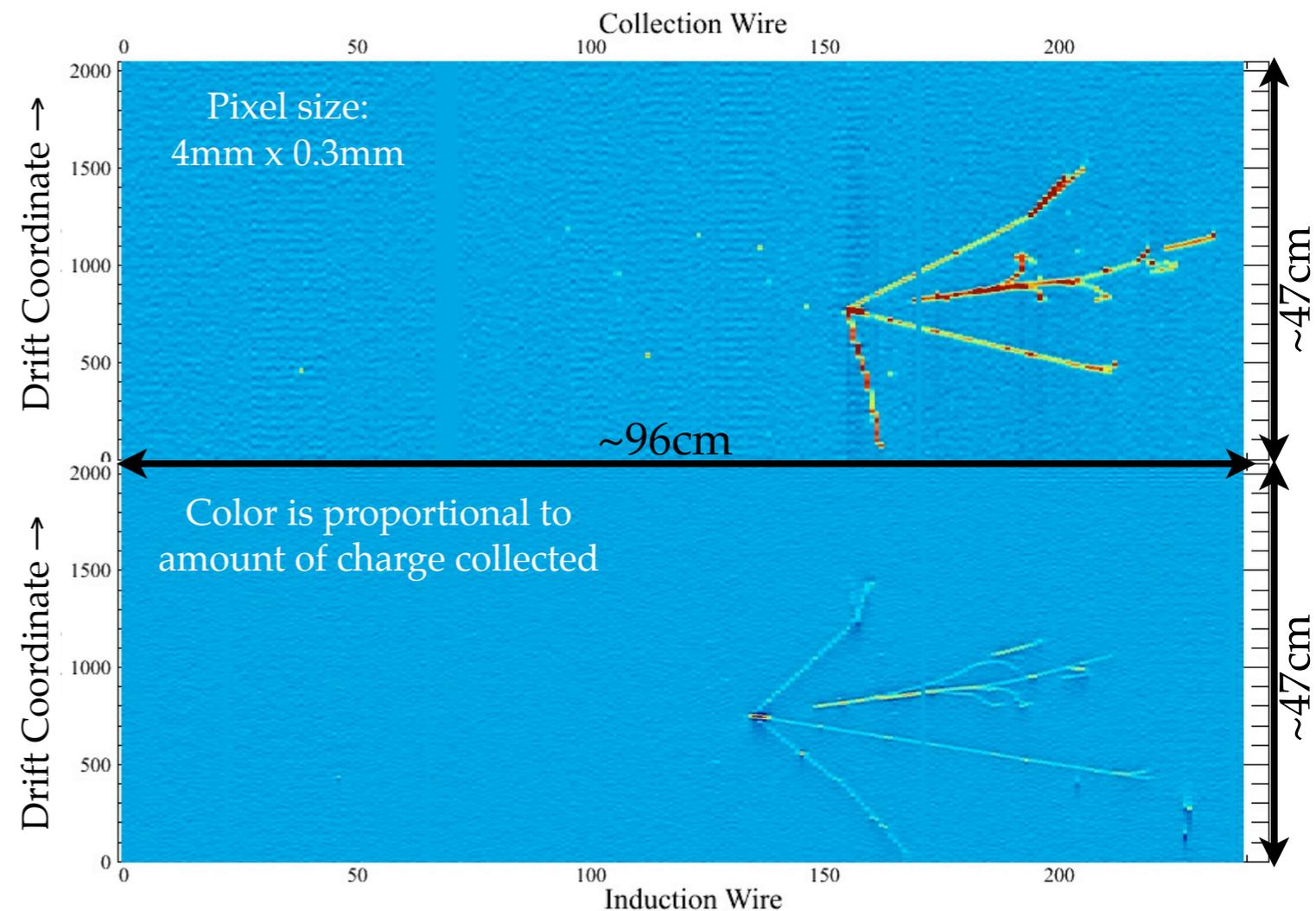
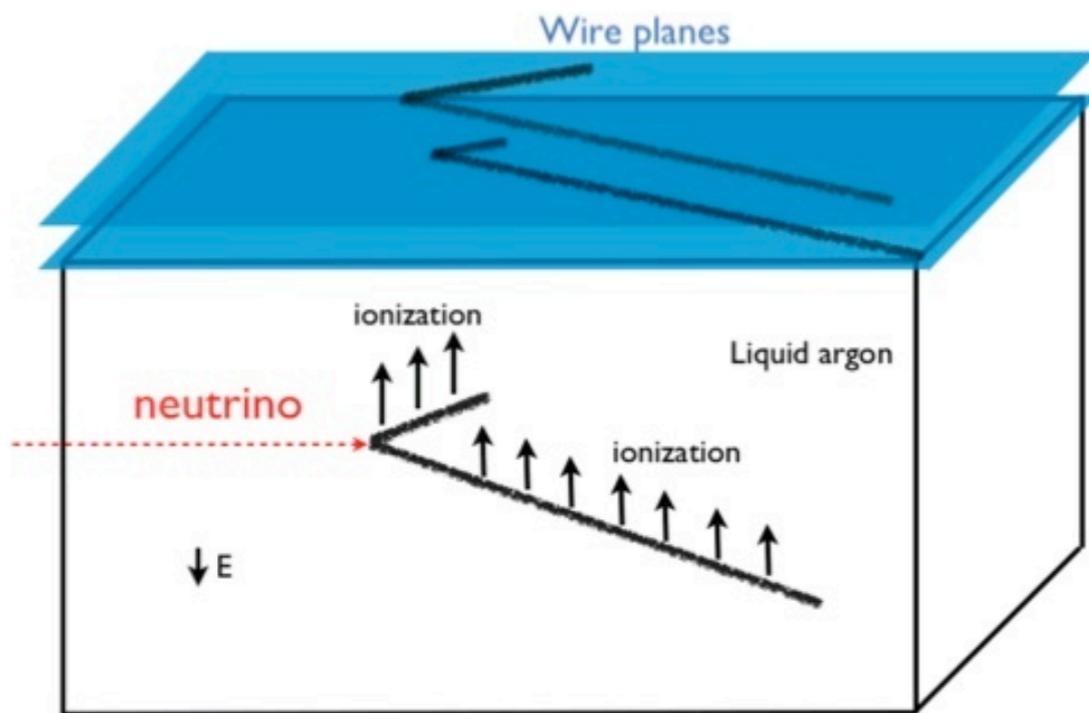


Introduction

- Liquid Argon Time Projection Chambers (LArTPCs) are imaging detectors that offer exceptional capabilities for studying neutrinos.
- The ArgoNeuT and MicroBooNE experiments, described in this talk, provide opportunities for interesting physics measurements and important LArTPC hardware development.

Liquid Argon Neutrino Detectors

- Ionization produced in neutrino interactions is drifted along E-field to highly segmented wireplanes.
- Timing of wire pulse information is combined with known drift speed to determine drift-direction coordinate.
- Calorimetry information is extracted from wire pulse characteristics.
- Copious scintillation light also available for collection and triggering.



ArgoNeuT Data Event

Refs:

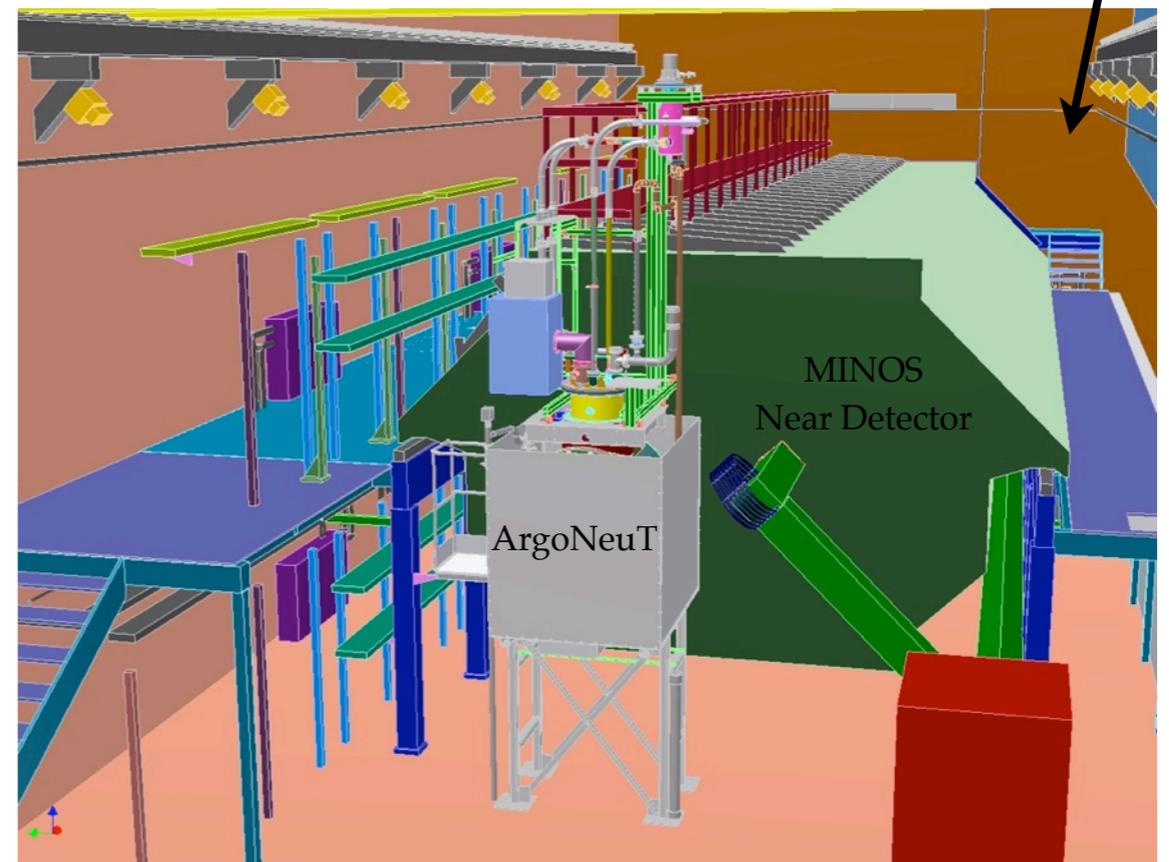
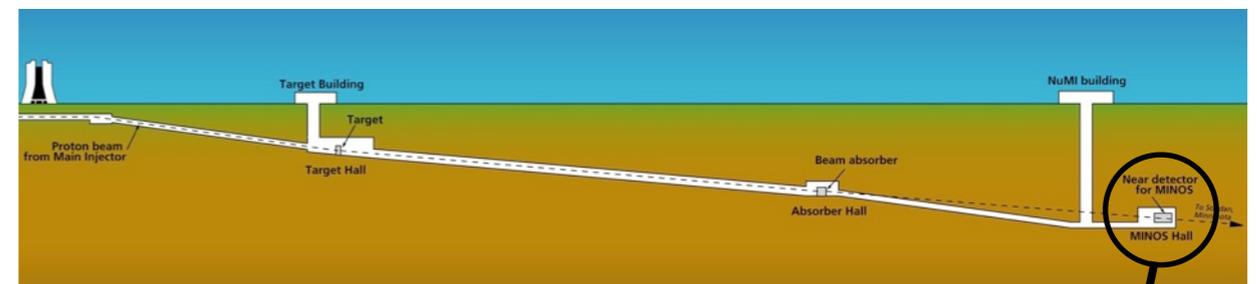
1.) *The Liquid-argon time projection chamber: a new concept for Neutrino Detector*, C. Rubbia, CERN-EP/77-08 (1977)

The ArgoNeuT Project

- ArgoNeuT (a.k.a. - Fermilab T962) deployed a ~175 liter LArTPC in Fermilab NuMI neutrino beam.
- Located directly upstream of MINOS near detector, which was used for full muon reconstruction.
- Collected 1.35×10^{20} Protons on Target (POT), predominantly in antineutrino mode.



NuMI Beam at Fermilab

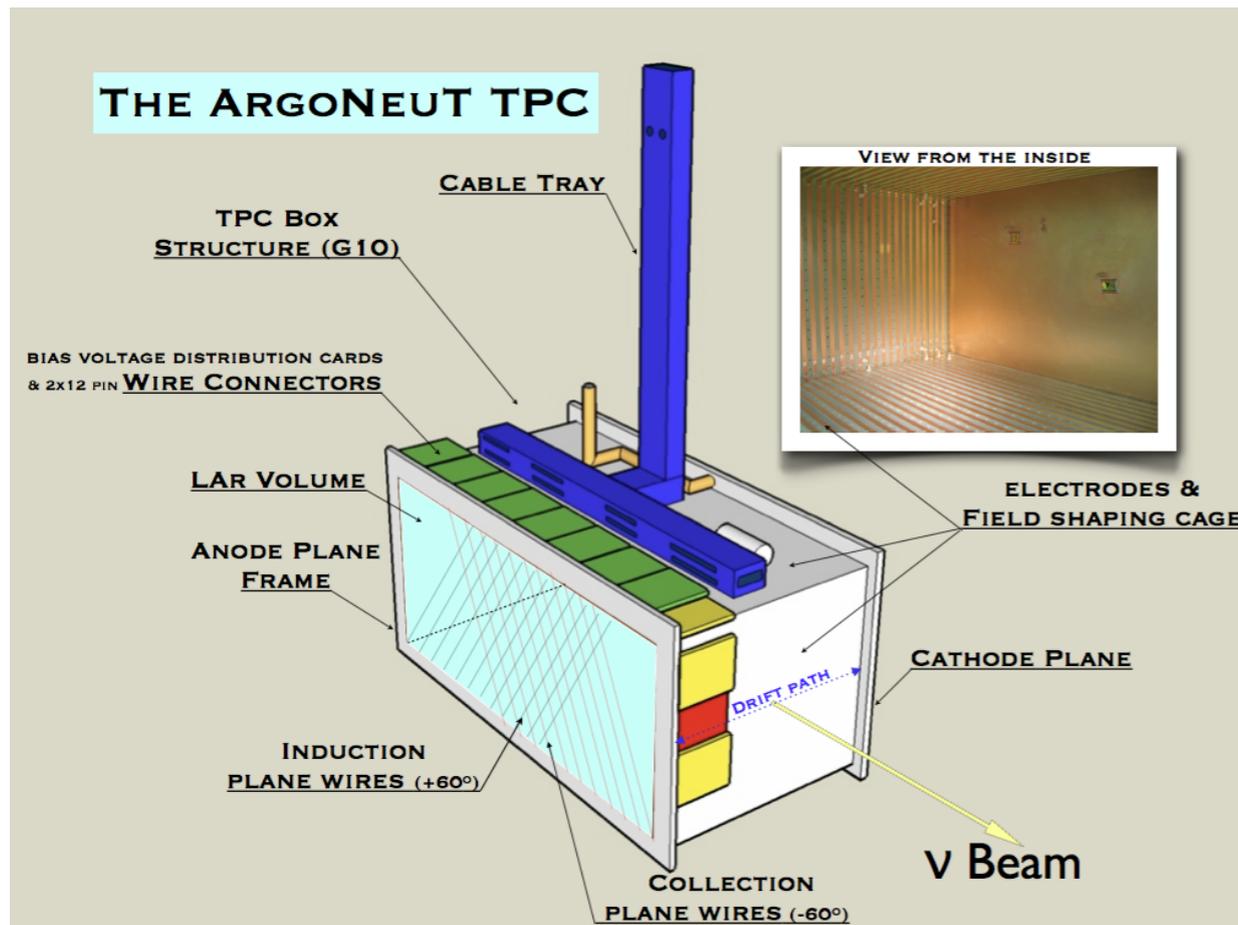


MINOS Hall at Fermilab

Refs:

1.) *The ArgoNeuT detector in the NuMI low-energy beam line at Fermilab*, C. Anderson et al., arXiv:1205.6747

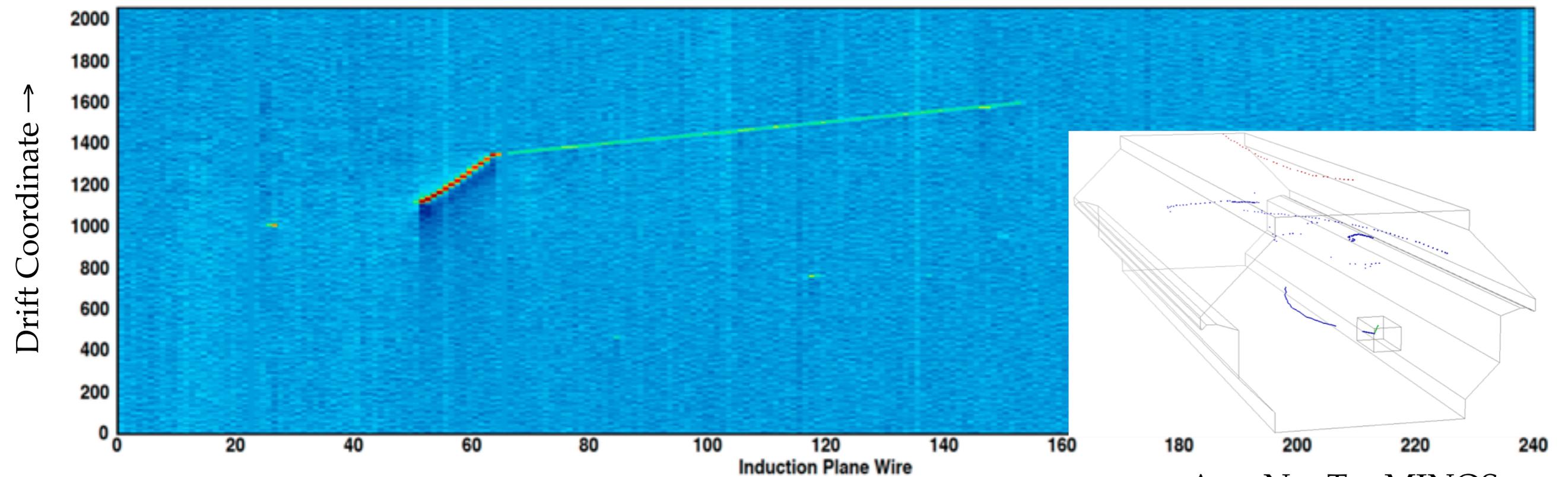
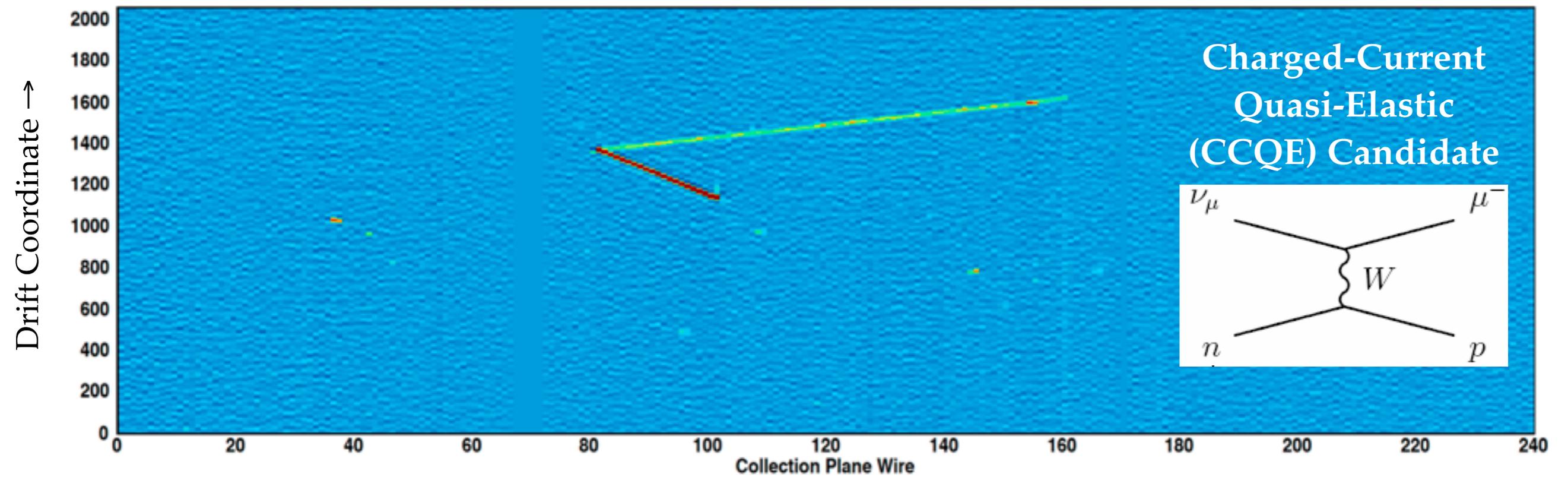
ArgoNeuT: Detector Details



ArgoNeuT in the NuMI Tunnel

Cryostat Volume	500 Liters
TPC Volume	175 Liters (90cm x 40cm x 47.5cm)
# Electronic Channels	480
Electronics Style (Temp.)	JFET (293 K)
Wire Pitch (Plane Separation)	4 mm (4 mm)
Electric Field	500 V / cm
Max. Drift Length (Time)	0.5 m (330 μ s)
Wire Properties	0.15mm diameter BeCu

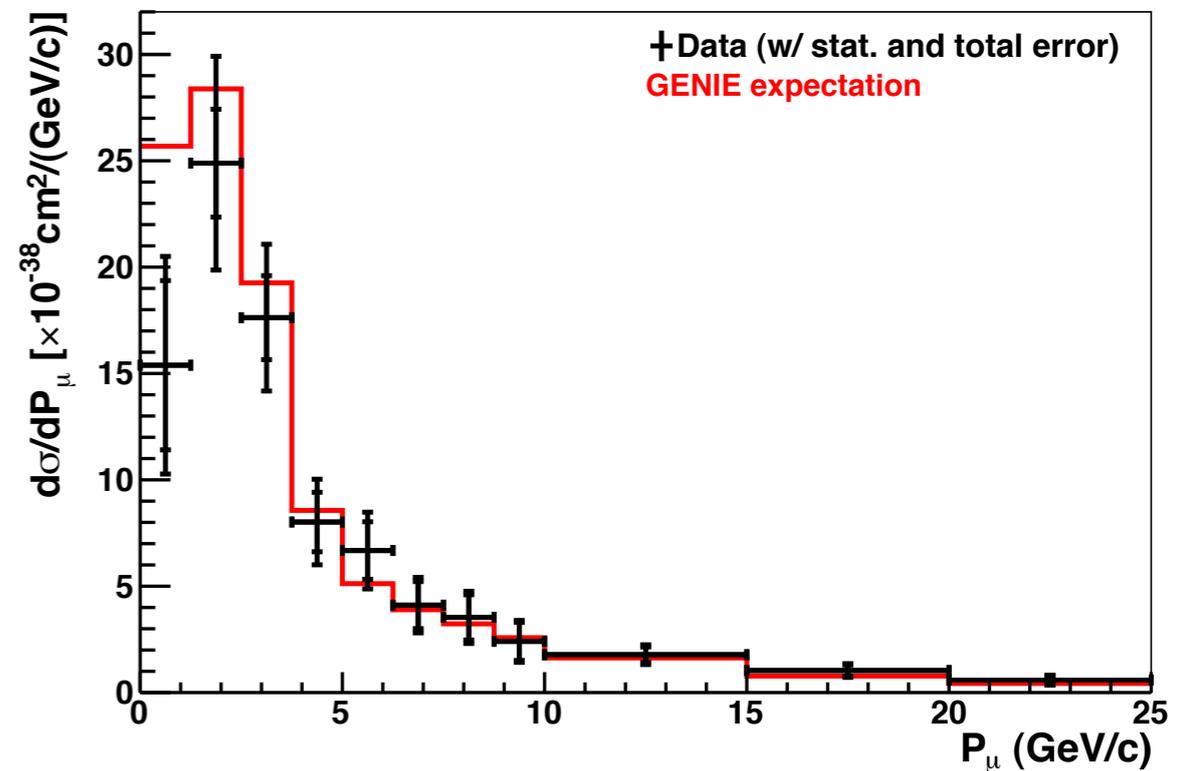
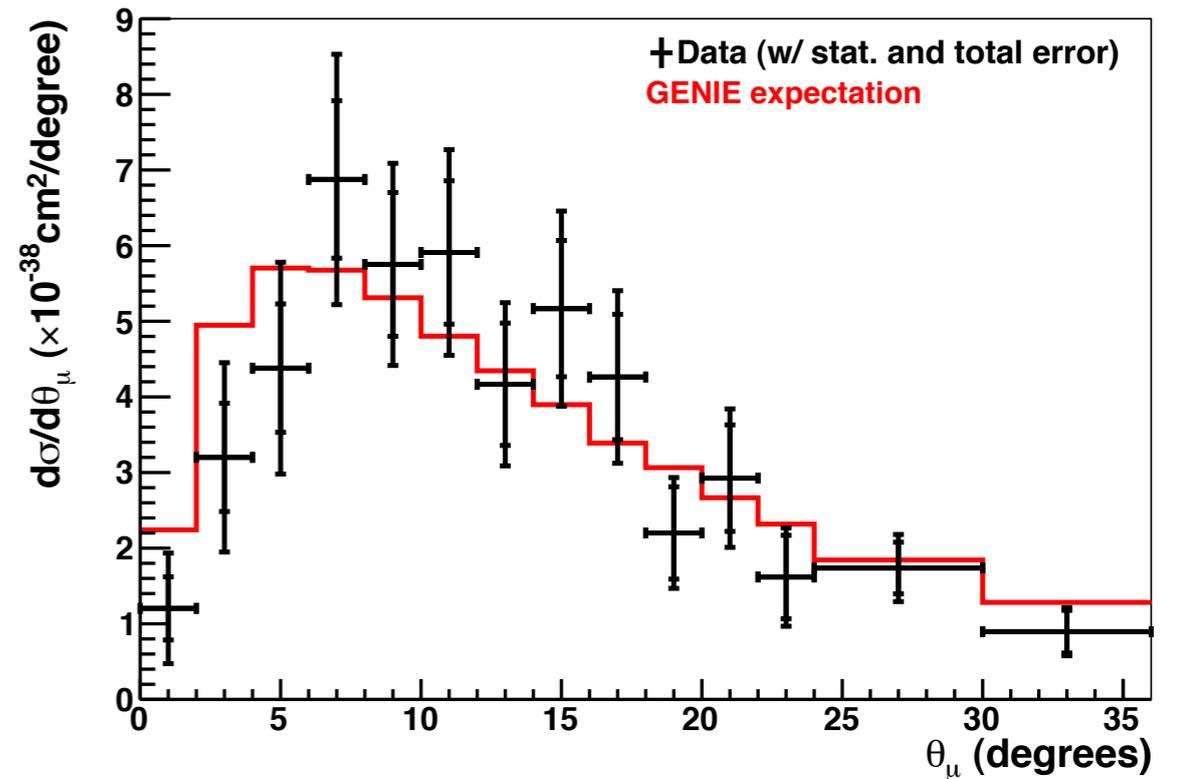
ArgoNeuT Data Event



ArgoNeuT + MINOS

- First Results: Using 2 weeks of neutrino-mode data (8.5×10^{18} POT), the differential cross-section for inclusive charged-current muon neutrino production was measured.
- Analysis Selection:
 - ▶ Track originating within ArgoNeuT fiducial region.
 - ▶ Match to corresponding track in MINOS near detector.
 - ▶ MINOS track is negatively charged.

$$\frac{\partial \sigma(u_i)}{\partial u} = \frac{N_{\text{measured},i} - N_{\text{background},i}}{\Delta u_i \epsilon_i N_{\text{targ}} \Phi}$$



Inclusive CC cross-section

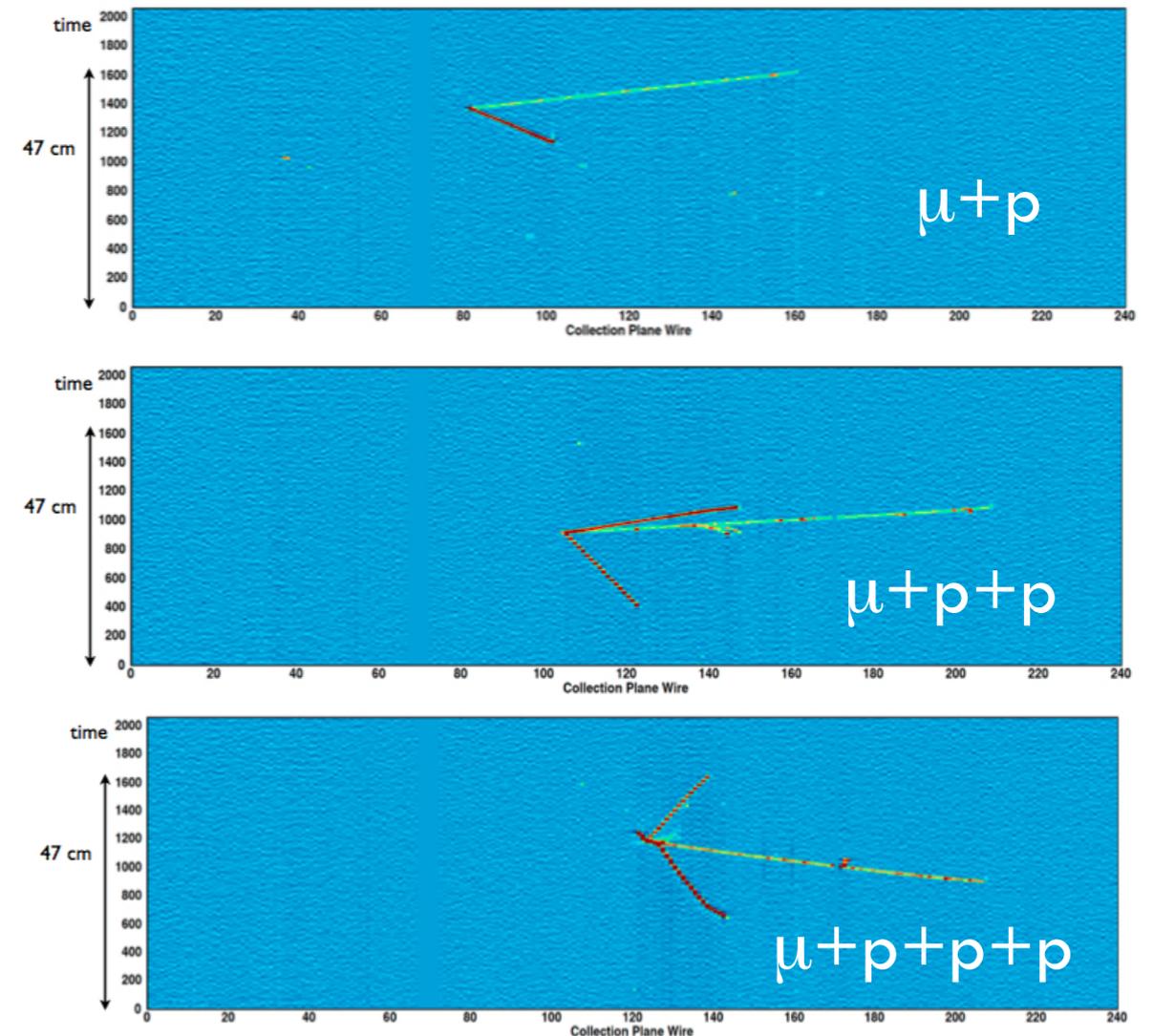
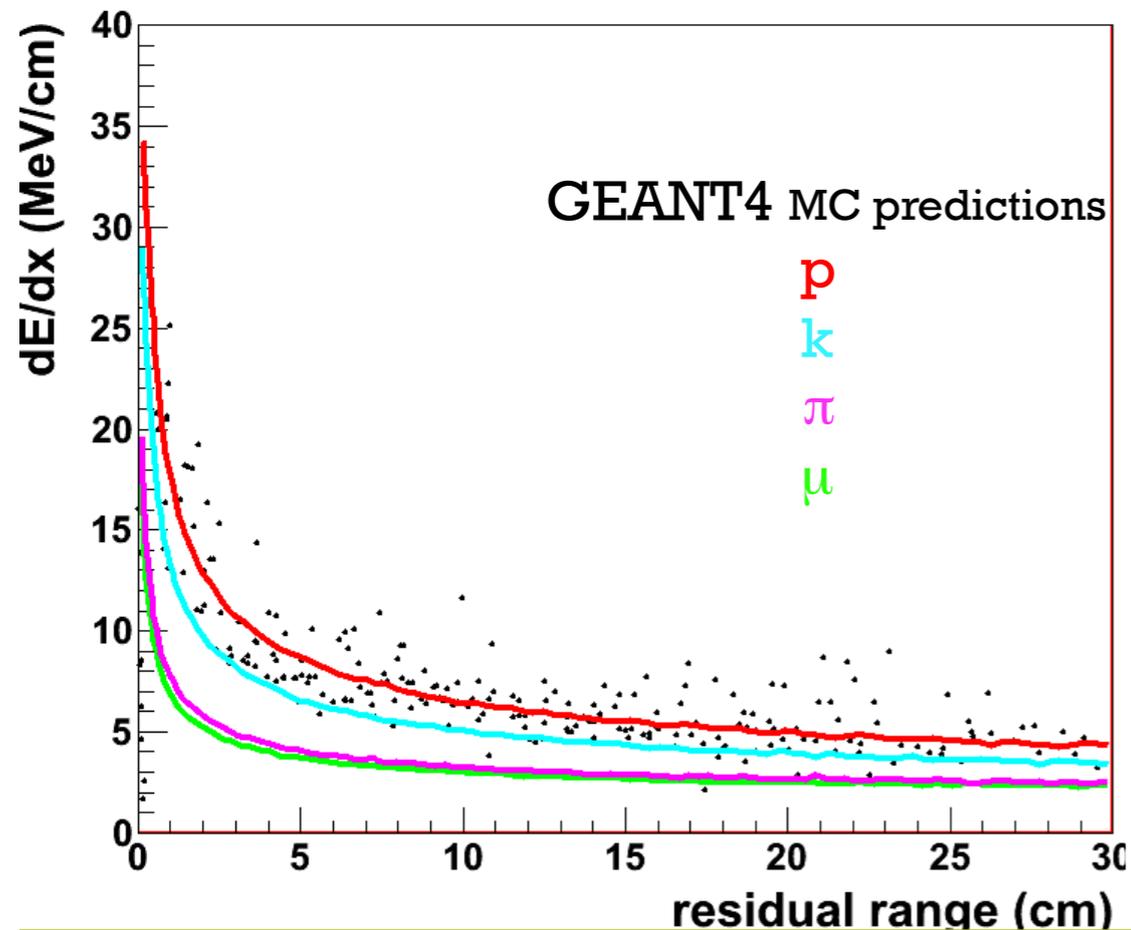
Refs:

1.) *First Measurements of Inclusive Muon Neutrino Charged Current Differential Cross Sections on Argon*, C. Anderson et al., PRL 108 (2012) 161802, arXiv:1111.0103

- Analyses in Progress:

- ▶ Charged-Current Inclusive cross-section in antineutrino mode.
- ▶ Charged-Current Quasi-Elastic exclusive analysis.
- ▶ Stopping Protons to measure recombination behavior.
- ▶ Hyperon Production.
- ▶ Initial measurements of dE/dx Particle ID effectiveness.

- Multinucleon Correlations, producing additional final-state activity, should be observable in ArgoNeuT.

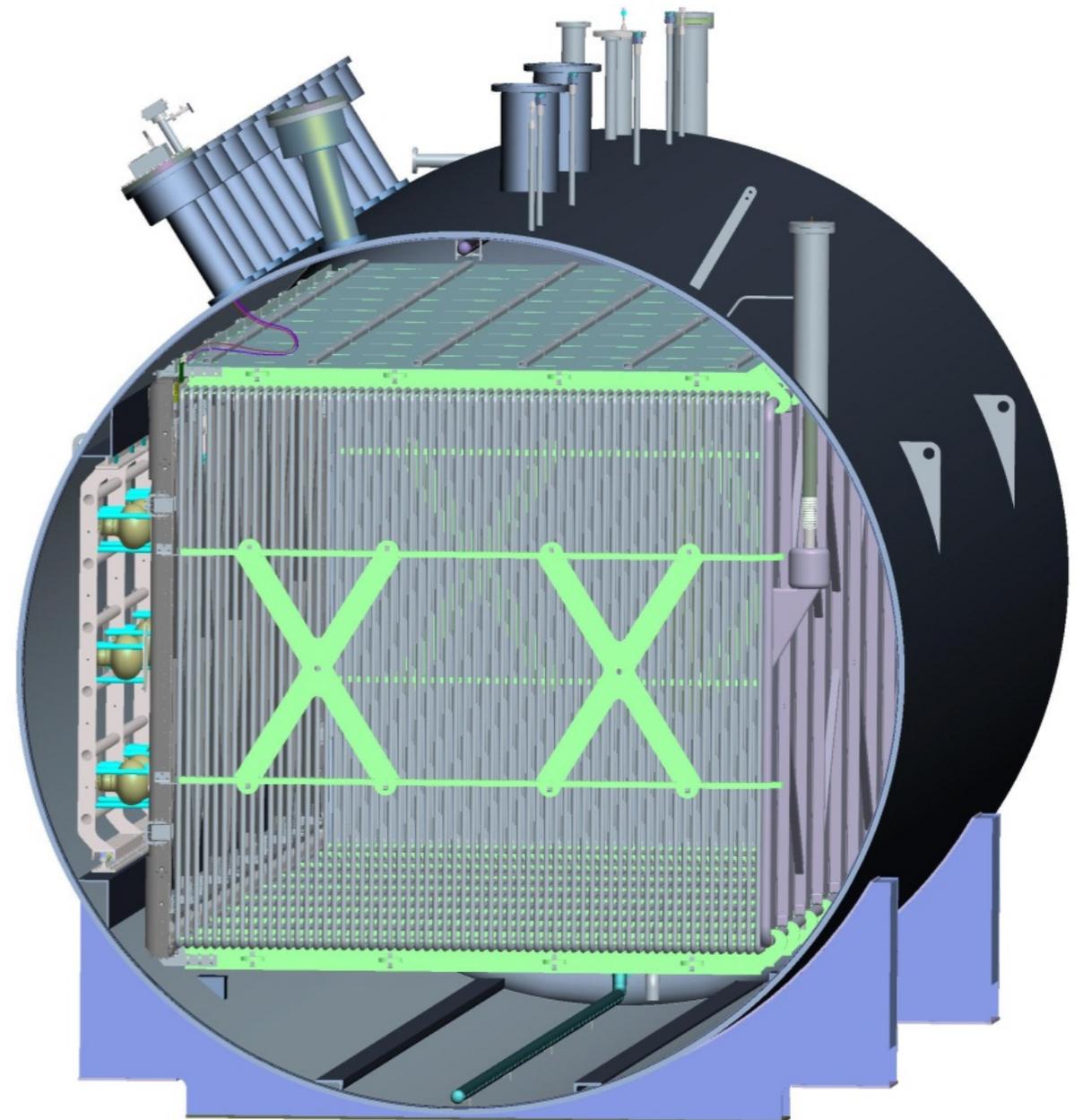


The MicroBooNE Experiment

- MicroBooNE will operate in the Booster neutrino beam at Fermilab starting in early 2014.
- Combines timely **physics** with **hardware** R&D necessary for the evolution of LArTPCs.
 - ▶ MiniBooNE low-energy excess
 - ▶ Low-Energy Cross-Sections
 - ▶ Cold Electronics (preamplifier in liquid)
 - ▶ Long drift (2.5m)



Booster Neutrino Beam at Fermilab



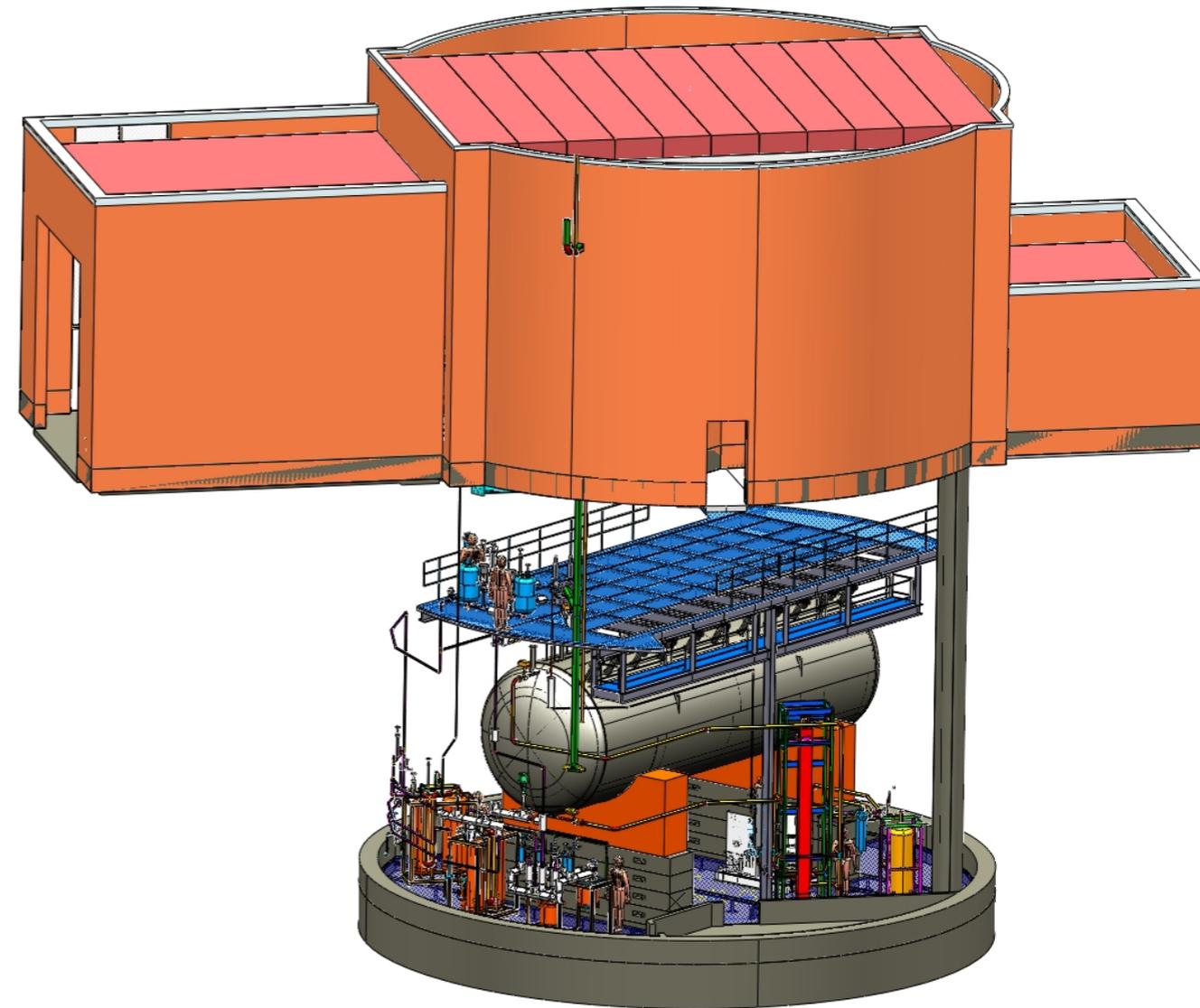
MicroBooNE Detector

MicroBooNE: Detector Details

- MicroBooNE will be located in new Liquid Argon Test Facility (LArTF), just upstream of MiniBooNE location.
- Building construction is well underway.



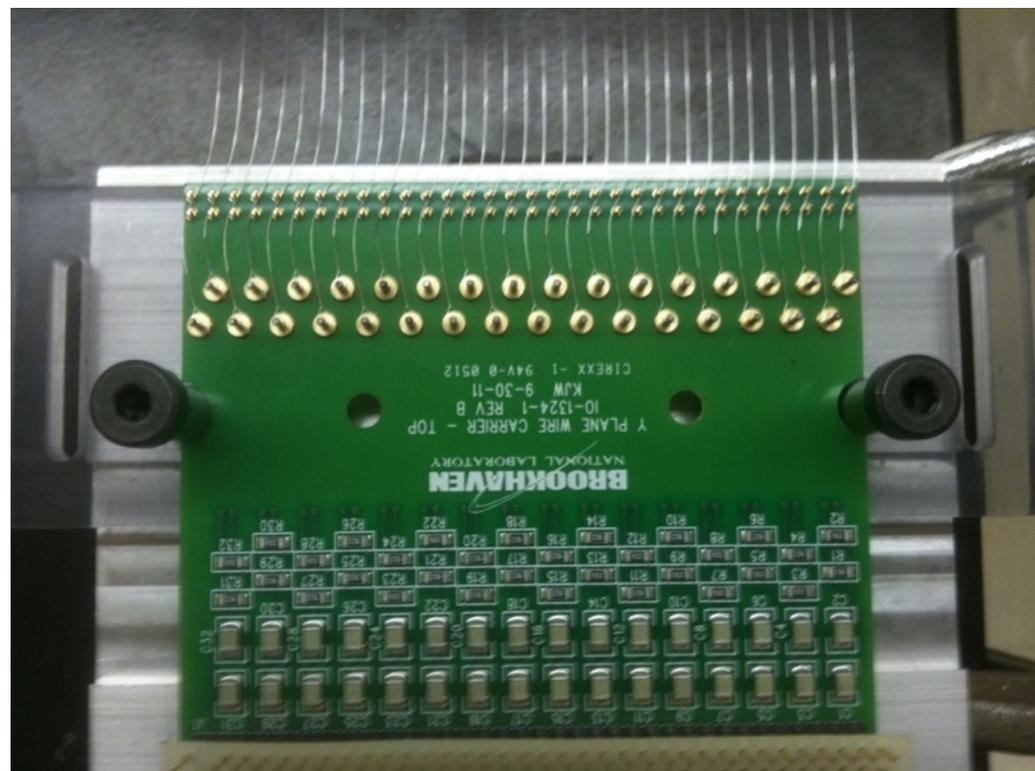
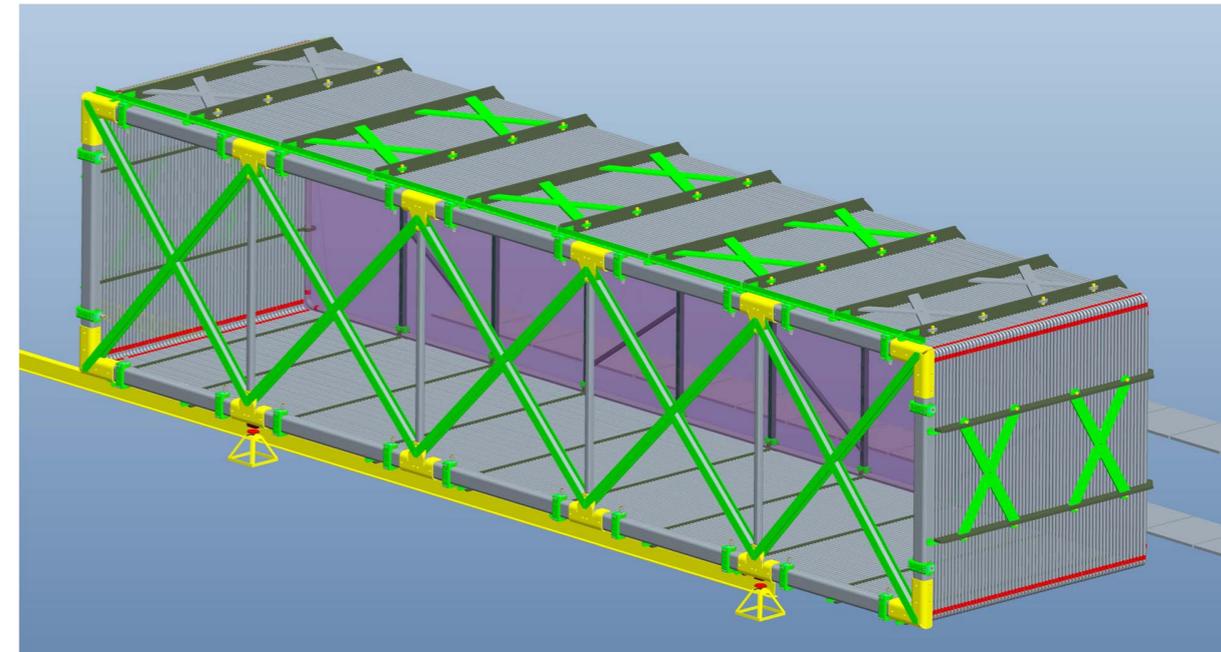
Liquid Argon Test Facility: June 2012



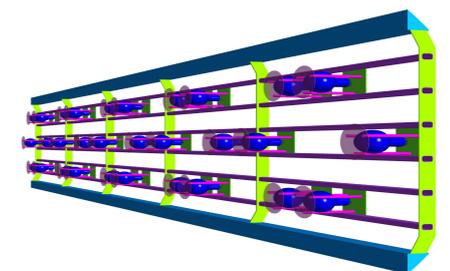
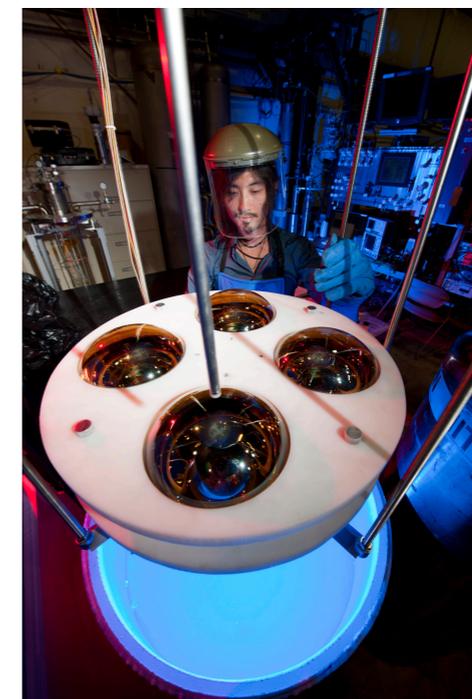
MicroBooNE Layout

MicroBooNE: Detector Details

Cryostat Volume	150 Tons
TPC Volume (l x w x h)	89 Tons (10.4m x 2.5m x 2.3m)
# Electronic Channels	8256
Electronics Style (Temp.)	CMOS (87 K)
Wire Pitch (Plane Separation)	3 mm (3mm)
Max. Drift Length (Time)	2.5m (1.5ms)
Wire Properties	0.15mm diameter SS, Cu/ Au plated
Light Collection	~30 8" Hamamatsu PMTs



Collection Plane Wire Assembly

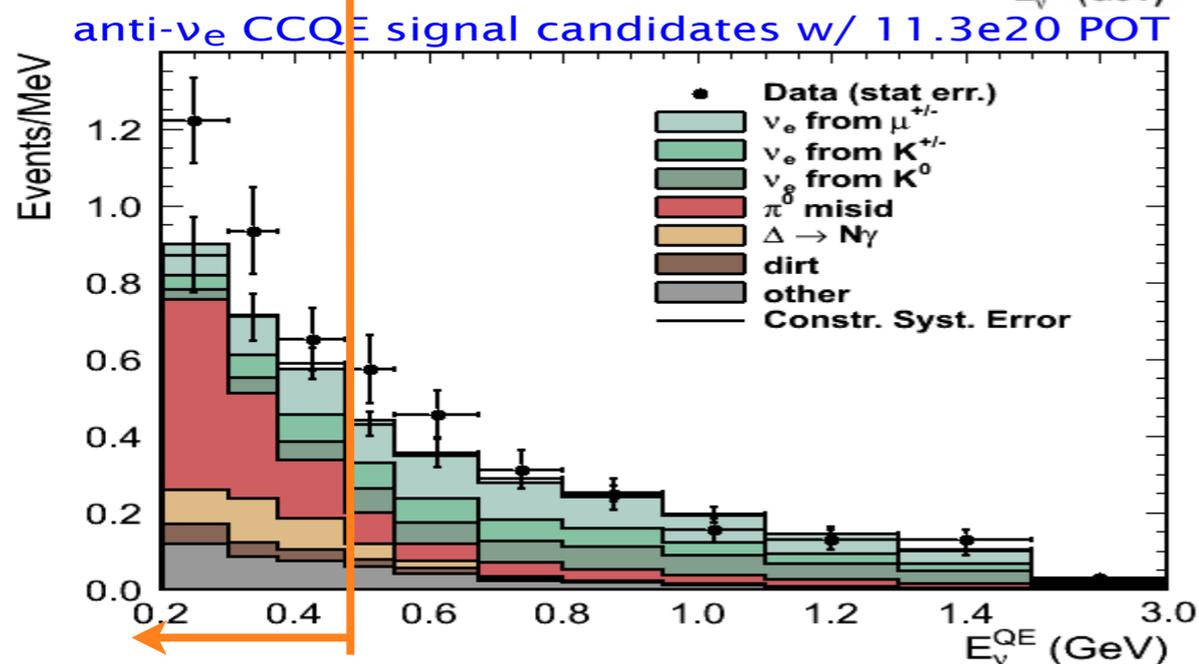
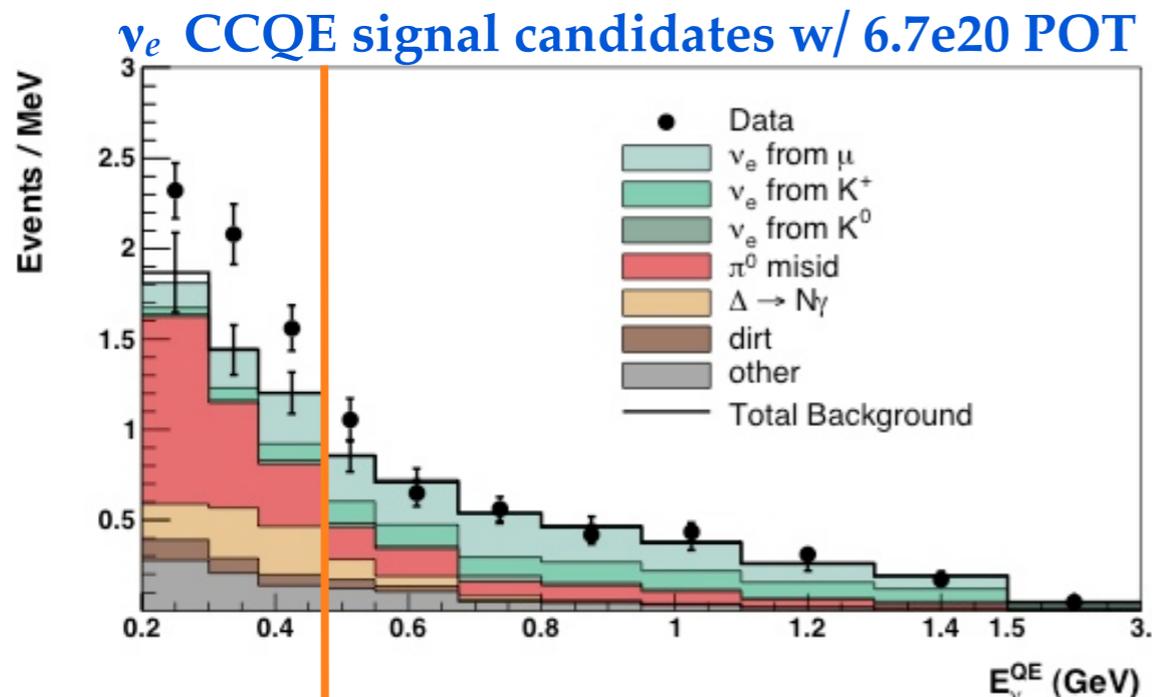


Teppei Katori and MicroBooNE PMTs:
IUPAP Young Scientist Prize Winner.
See his talk on Tue., July 10!

MicroBooNE: Physics

- Address the MiniBooNE low energy excess

- ▶ MiniBooNE is a Cerenkov detector that looks for ν_e appearance from a beam of ν_μ
- ▶ Does MicroBooNE confirm the excess?
- ▶ If confirmed, is the excess due to a electron-like or gamma-like process?



MiniBooNE ν_e Appearance Result

MiniBooNE Result Excess
(200-475 MeV)

Neutrino: 128.8 ± 43.4 events

AntiNeutrino: 57.9 ± 21.6 events

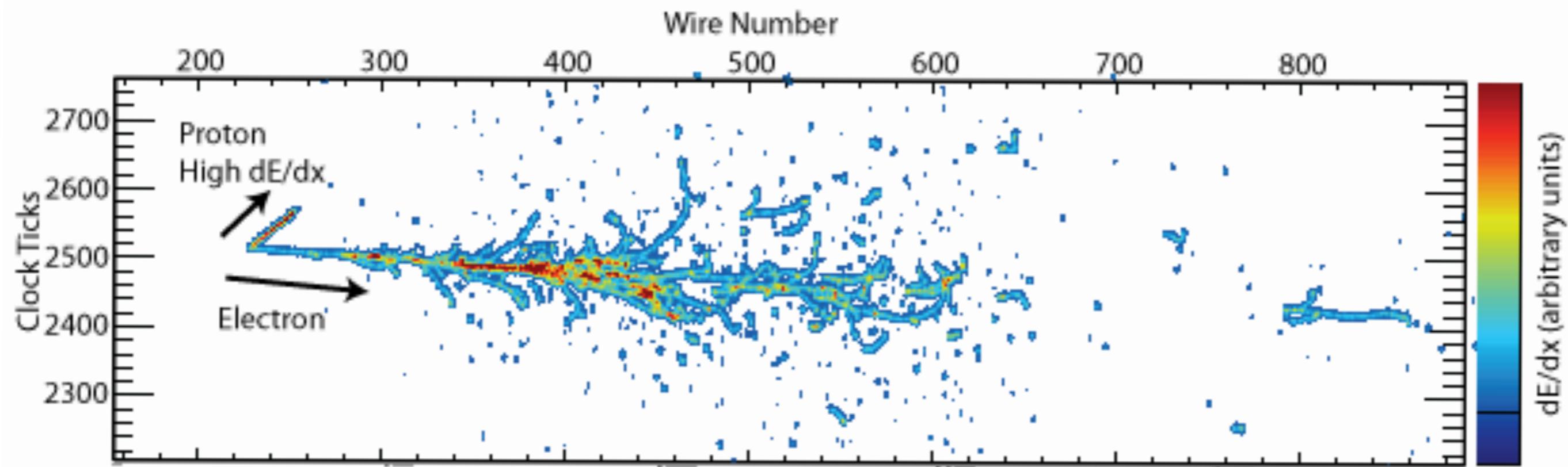
Refs:

1.) *Unexplained Excess of Electron-Like Events From a 1-GeV Neutrino Beam* MiniBooNE Collaboration, Phys. Rev. Lett. 102, 101802 (2009)

2.) *Updated Oscillation Results from MiniBooNE*, Chris Polly, Neutrino2012 Presentation

MicroBooNE: Physics

- Prove effectiveness of electron/ gamma separation technique (*e.g.* - using dE/dX information), and exploit to characterize any MiniBooNE-like “low-E” excess signals.
- Low Energy Cross-Section Measurements: CCQE, NC π^0 , $\Delta \rightarrow N\gamma$, etc...
- Study backgrounds relevant for Proton Decay searches in larger detectors (*e.g.* - Kaon production), and develop SuperNova analysis capabilities.
- Probe the Strange Quark content of Proton.
- Continue development of automated reconstruction (building on ArgoNeuT’s effort).



Example CCQE ν_e event simulated in MicroBooNE Collection Plane (zoomed in view)

Conclusions

- LArTPCs are powerful detectors for studying neutrinos.
- ArgoNeuT data analysis is ongoing. First results published, and will have more results later this year using full data sample.
- MicroBooNE construction is in progress, and operations will begin in early 2014. MicroBooNE will search for MiniBooNE low-Energy excess, and carry out extensive physics program.

Thanks



ArgoNeuT Collaboration

C. Anderson^a, M. Antonello^b, B. Baller^c, T. Bolton^d, C. Bromberg^e, F. Cavanna^{a,f}, E. Church^a, D. Edmunds^e, A. Ereditato^g, S. Farooq^d, B. Fleming^a, H. Greenlee^c, R. Guenette^a, S. Haug^g, G. Horton-Smith^d, C. James^c, E. Klein^a, K. Lang^h, P. Laurens^e, S. Linden^a, D. McKee^d, R. Mehdiyev^h, B. Page^e, O. Palamara^{a,b,*}, K. Partyka^a, G. Rameika^c, B. Rebel^c, B. Rossi^g, M. Soderberg^{c,i,†}, J. Spitz^a, A.M. Szelc^a, M. Weber^g, T. Yang^c, G.P. Zeller^c

^aYale University, New Haven, CT 06520 USA

^bINFN - Laboratori Nazionali del Gran Sasso, Assergi, Italy

^cFermi National Accelerator Laboratory, Batavia, IL 60510 USA

^dKansas State University, Manhattan, KS 66506 USA

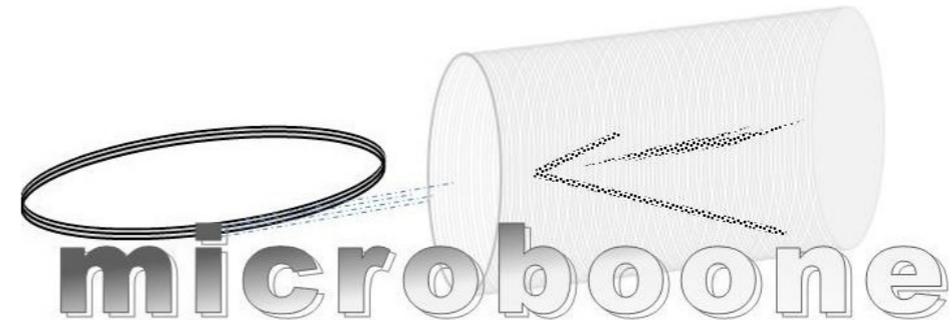
^eMichigan State University, East Lansing, MI 48824 USA

^fUniversita dell'Aquila e INFN, L'Aquila, Italy

^gUniversity of Bern, Bern, Switzerland

^hThe University of Texas at Austin, Austin, TX 78712 USA

ⁱSyracuse University, Syracuse, NY 13244 USA



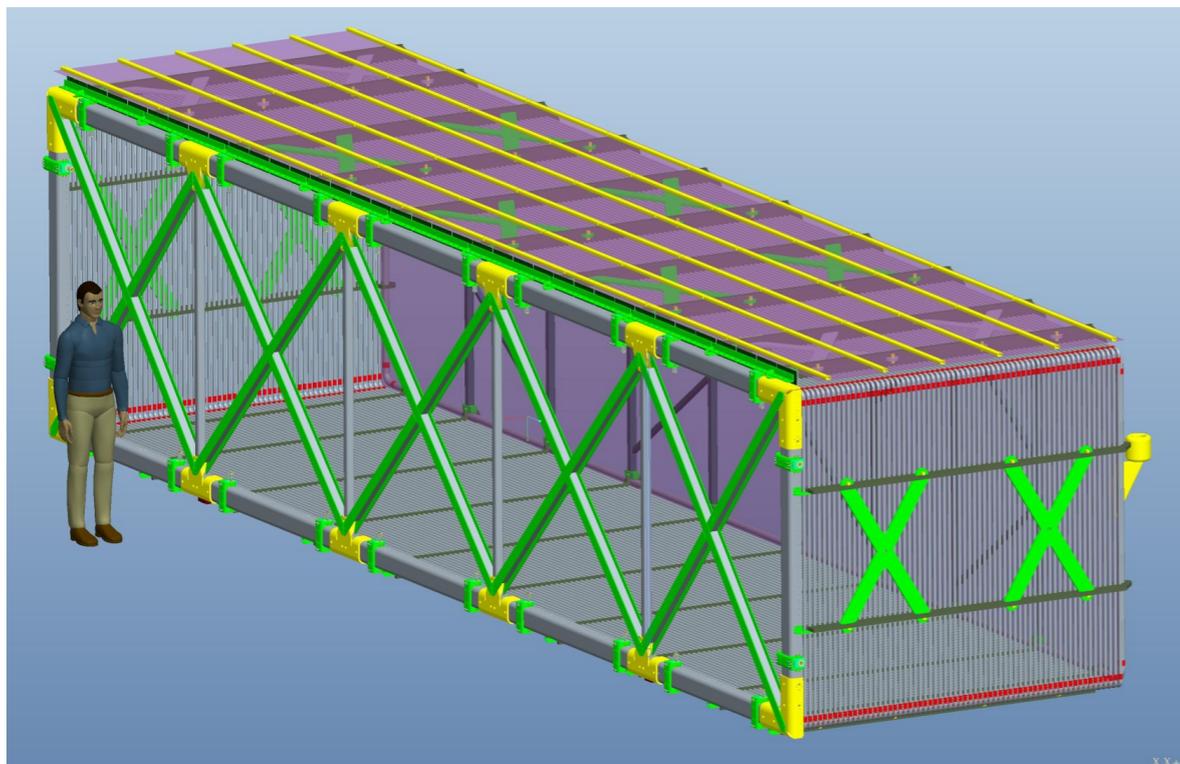
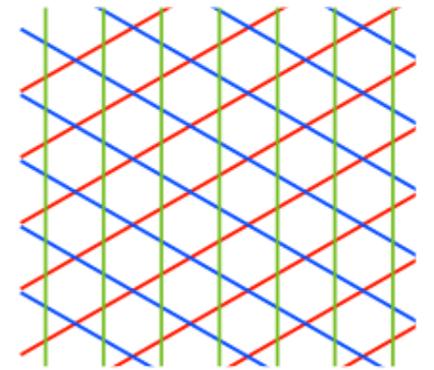
MicroBooNE Collaboration

- **Brookhaven Lab** H. Chen, S. Duffin, J. Farrell, F. Lanni, Y. Li, D. Lissauer, G. Mahler, D. Makowieki, J. Mead, V. Radeka, S. Rescia, J. Sondericker, C. Thorn, K. Wu, B. Yu
- **Columbia University** L. Camilleri, R. Carr, G. Cheng, C. Chi, G. Karagiorgi, C. Mariani, B. Seligman, M. Shaevitz, B. Sippach, B. Willis
- **Fermilab** B. Baller, D. Bogert, B. Carls, H. Greenlee, C. James, H. Jostlein, M. Kirby, S. Lockwitz, B. Lundberg, S. Pordes, J. Raaf, G. Rameika, B. Rebel, R. Schmitt, D. Schmitz, J. Wu, T. Yang, S. Zeller
- **Instituto Nazionale di Fisica Nucleare, Italy** F. Cavanna, O. Palamara
- **Kansas State University** T. Bolton, D. McKee, G. Horton-Smith
- **Laboratory for High Energy Physics, University of Bern, Switzerland** A. Ereditato, I. Kreslo, T. Strauss, C. von Rohr, M. Weber
- **Los Alamos Lab** G. Garvey, J. Gonzales, B. Louis, C. Mauger, G. Mills, Z. Pavlovic, R. Van de Water, H. White
- **Massachusetts Institute of Technology** W. Barletta, L. Bugel, J. Conrad, C. Ignarra, B. Jones, T. Katori, A. Prakash, T. Smidt
- **Michigan State University** C. Bromberg, D. Edmunds
- **New Mexico State University** V. Papavassiliou
- **Princeton University** Q. He, C. Lu, K. McDonald
- **St. Mary's University** P. Nienaber
- **Syracuse University** M. Asaadi, M. Soderberg
- **University of Cincinnati** R. Grosso, R. Johnson, B. Littlejohn
- **University of Texas at Austin** S. Kopp, K. Lang, R. Mehdiyev
- **Yale University** C. Brasco, E. Church, B. Fleming, R. Guenette, E. Klein, A. Szelc

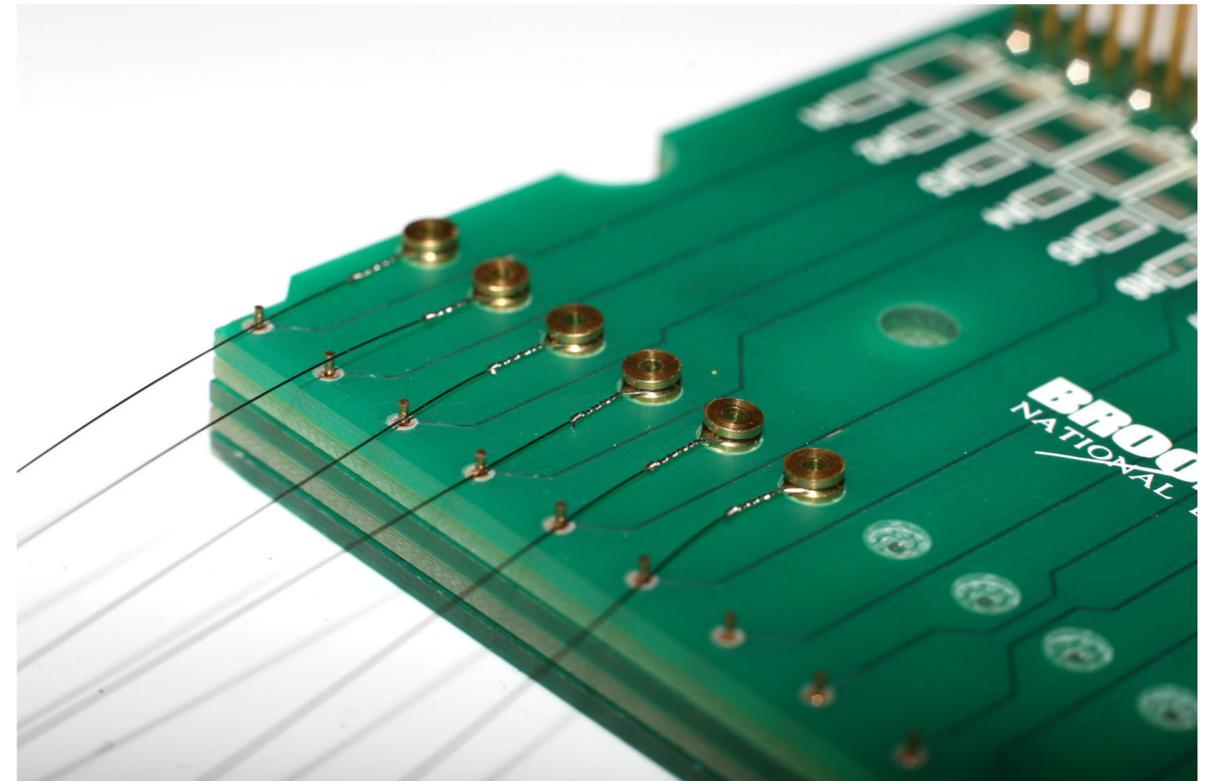
Back-Up Slides

MicroBooNE: TPC

- TPC has 3 instrumented wireplanes (Two Induction at $\pm 60^\circ$ from vertical, One Collection with vertical wires).
- Cathode is held at -125kV , setting up 500V/cm drift field.
- Wires are individually terminated around brass ferrules, then positioned on wire carriers.



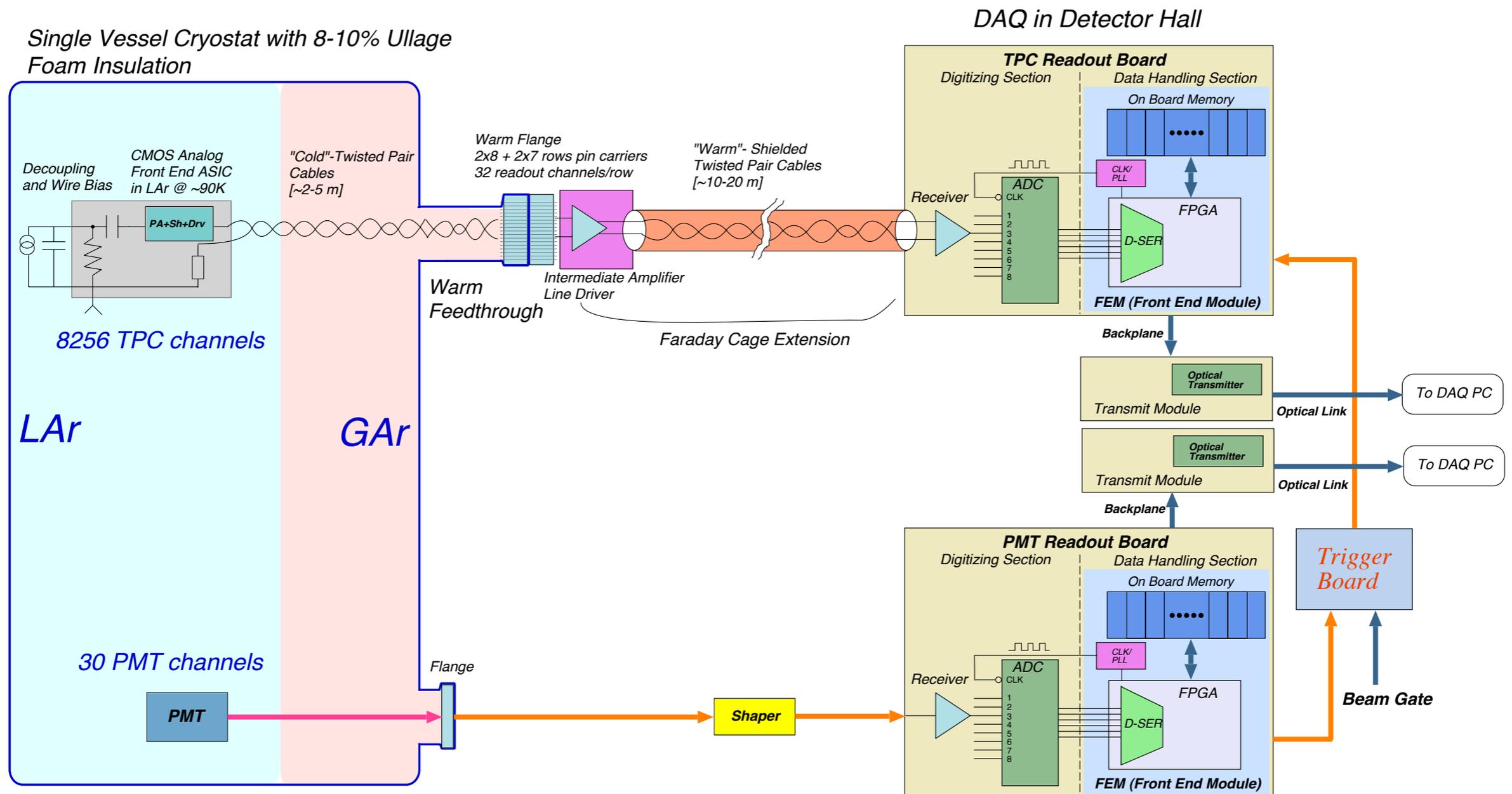
Schematic of MicroBooNE TPC



Prototype wires and wire carrier boards.

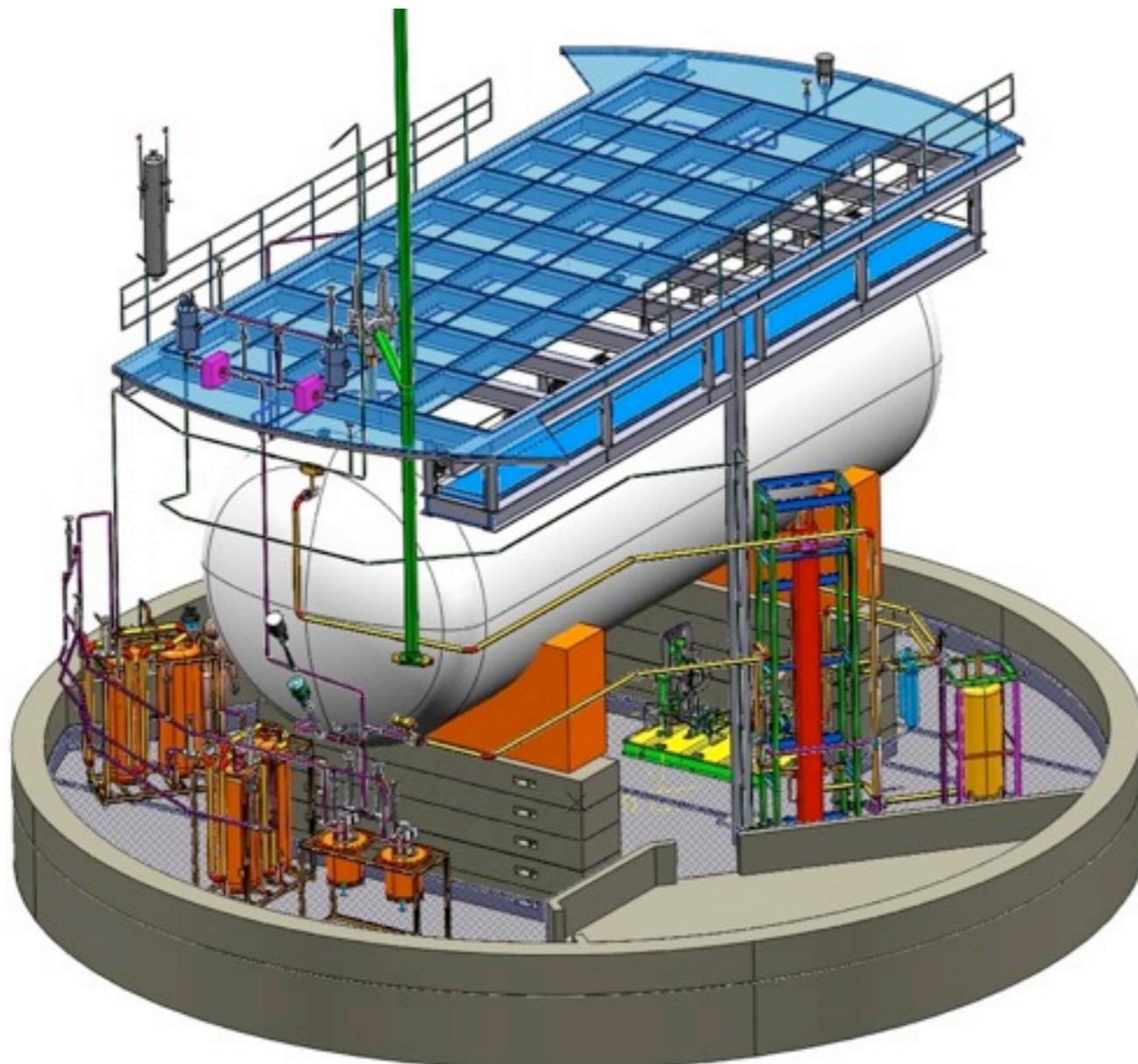
MicroBooNE: Electronics

- CMOS preamplifiers located in liquid, attached to TPC.
- 12-bit ADCs sampled at 2MHz (i.e. - 500ns per sample) for 4.8ms (x3 drift window).
- 1-hour data buffering for Supernova detection signal from SNEWS.



MicroBooNE: Cryogenics

- Cryogenic system consists of filters/pumps/etc... for circulating and purifying LAr.
- Cryostat is evacuable (though the plan is not to evacuate) and foam insulated.



Schematic of MicroBooNE Layout



LAPD @ Fermilab

Why Noble Liquids for Neutrinos?

- Abundant ionization electrons and scintillation light can both be used for detection.
- If liquids are highly purified (<0.1 ppb), ionization can be drifted over long distances.
- Excellent dielectric properties accommodate very large voltages.
- Noble liquids are dense, so they make a good target for neutrinos.
- Argon is relatively cheap and easy to obtain (1% of atmosphere).
- Drawbacks?...no free protons...nuclear effects.



Boiling Point [K] @ 1atm	4.2	27.1	87.3	120.0	165.0	373
Density [g/cm ³]	0.125	1.2	1.4	2.4	3.0	1
Radiation Length [cm]	755.2	24.0	14.0	4.9	2.8	36.1
dE/dx [MeV/cm]	0.24	1.4	2.1	3.0	3.8	1.9
Scintillation [γ /MeV]	19,000	30,000	40,000	25,000	42,000	
Scintillation λ [nm]	80	78	128	150	175	

ArgoNeuT Data Event

